µ-RayStation: an adaptation of RayStation 5 for small animal radiotherapy

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Introduction and Objectives

Modern pre-clinical radiotherapy allows to mimic 3D image-guided clinical radiotherapy:

- beam size, targeting accuracy and image resolution are scaled-down;
- beam energy is reduced from MV to kV.

In our institution, the XRAD225Cx µ-irradiator is used for pre-clinical studies and a Monte Carlo model (GATEv7) was previously created and validated[(1,2)] for dose calculation in small animals. However, typical MC environments do not provide the same tools that are available in a clinical treatment planning system (TPS) to manage patient workflow and irradiation.

The goal of this work was to adapt a clinical TPS in order to take into account the constraints and requirements of pre-clinical irradiations and to benefit from all the features.

Fig 1: XRAD225Cx preclinical irradiator

Material and Method

µ-RayStation (µ-RS) was derived from RayStation v5. A model of the XRAD225Cx was created based on measurements, allowing arc and static beams for 7 cylindrical collimators from 20mm to 1mm of diameter. Dose distributions are calculated with a Monte Carlo algorithm (VMC++) [(3,4)]. Calculations were compared with EBT3 measurements in water for all static beams and with GATE in heterogeneous media (a 5mm static beam in layers of water/bone/lung/water) and a mouse CT for 5mm static and arc beams.

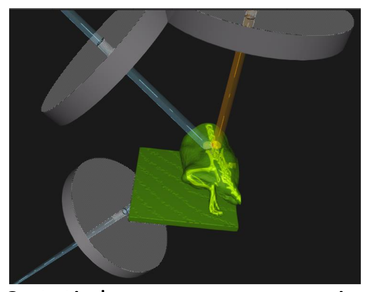


Fig 2: 3 static beams on a mouse in µ-RS

Results

Comparison in water

Fig 3: In-plane dose profiles for all collimators

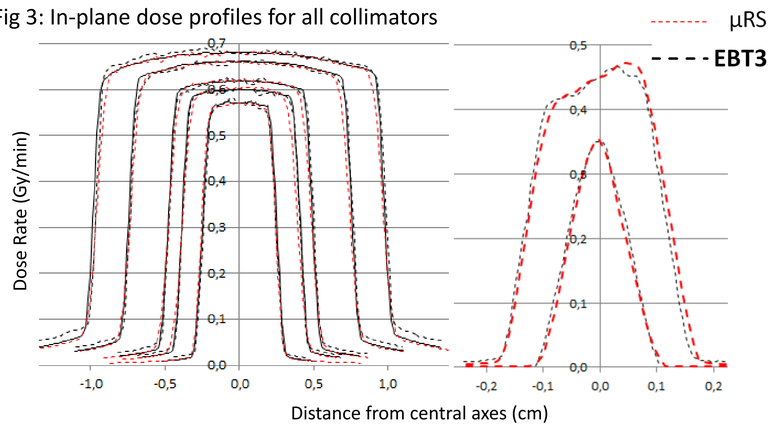
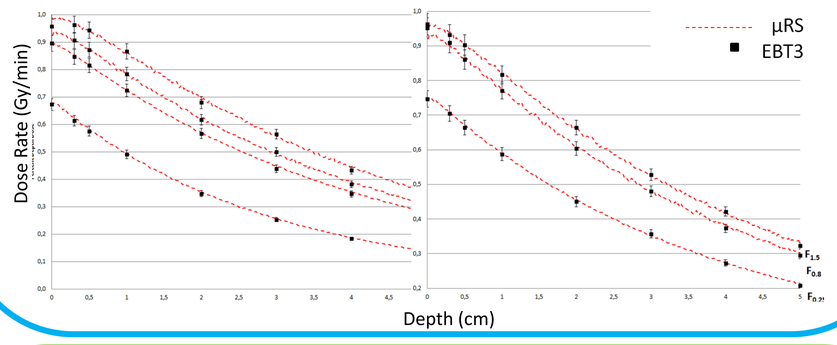
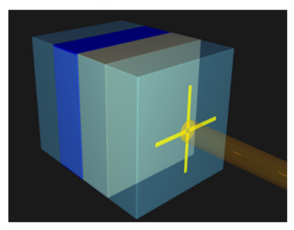


Fig 4: Percent Depth Dose for all collimators



Comparison in heterogeneous media



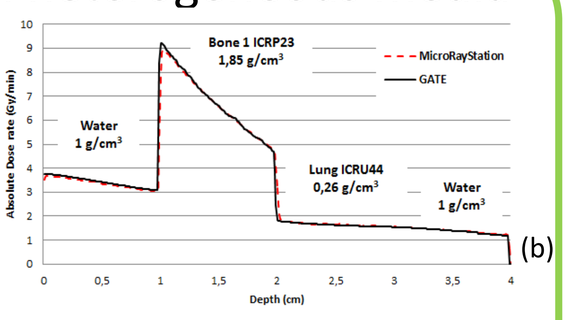
(a)

Out of interface areas

Material	Mean absolute error (%)
Water	1,7
Bone	0,7
Lung	1,2
Water	1,2

(c)

At interfaces: DTA = 0,1 mm



(b)

Grid resolution: 0,1x0,1x0,1mm³
µ-Raystation RSU = 0,21 %
GATE RSU = 0,87 %

Fig 5: virtual heterogeneous phantom (a). Absolute dose rate in depth calculated with µ-RS and Gate in the heterogeneous phantom (b). Table of mean absolute error (%) between µ-RS and Gatefor each medium (c).

Comparison in mouse

Grid resolution: 0,2x0,2x0,2mm³
µ-RayStation RSU < 0,34 % for each beam
GATE RSU = 0,65 % for total dose

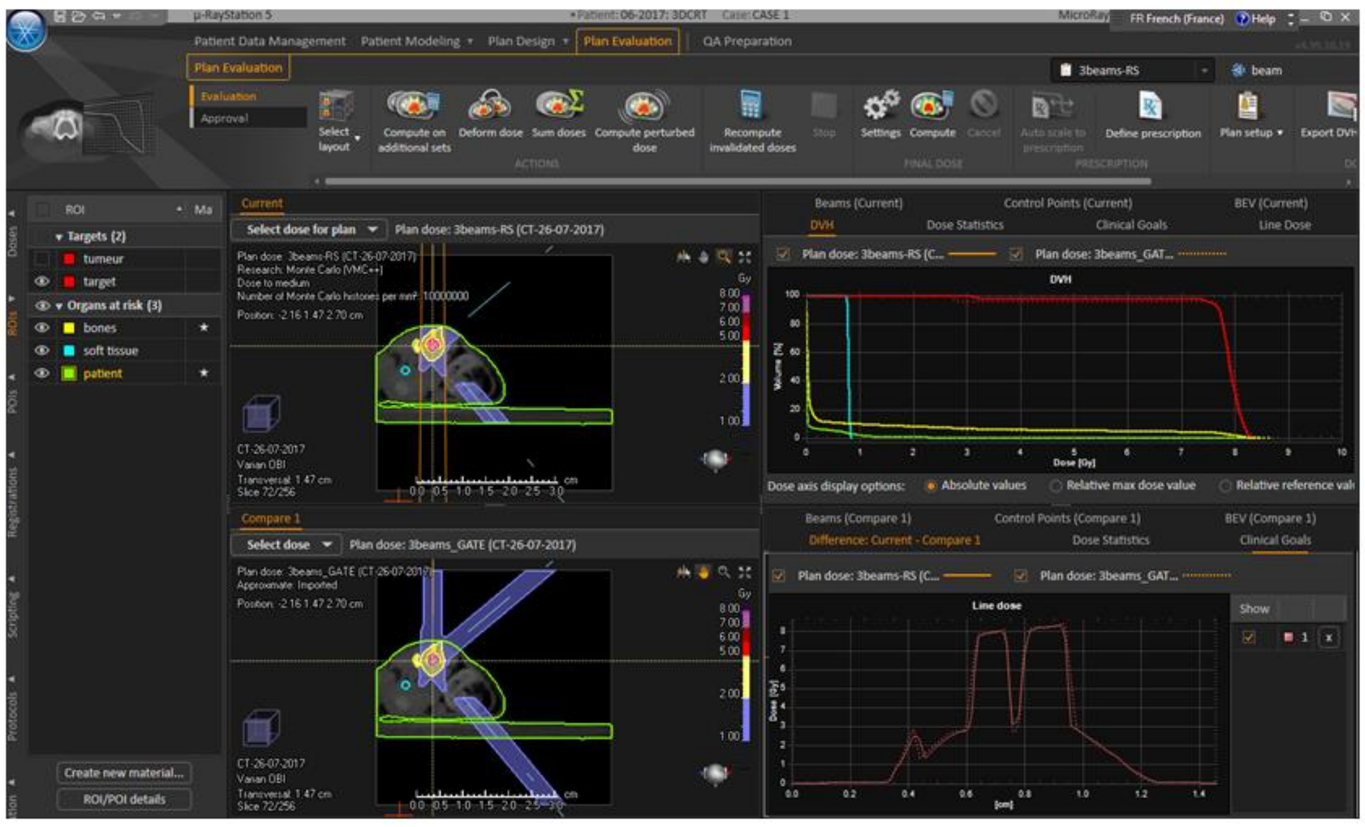


Fig 6: Plan evaluation interface in µ-RS. Dose Volume-Histogram and profiles comparison between µ-RS (up) and Gate (down) dose distributions for 3 static beams.

Plan at isocenter	1 % ; 0,3 mm	1 % ; 0,2 mm
axial	99,5	95,0
sagittal	99,6	97,2
coronal	99,9	95,3

Plan at isocenter	1 % ; 0,3 mm	1 % ; 0,2 mm
axial	99,2	95,1
sagittal	99,7	98,0
coronal	99,5	97,2

Fig 7: A γ-analysis was performed between µ-RS and Gate with Verisoft®. Tables present the % pixels local-γ passed criteria (1%; 0,3mm and 1%;0,2mm), inside isodose 20%, for the 3 plans crossing the isocenter. Left table presents results for the 3 static beams γ-analysis and right table for the arc γ-analysis .

Conclusion

µ-RayStation is a complete TPS, adapted and fully validated for pre-clinical irradiations. A large set of relevant clinical tools available in RayStation v5 can be applied for pre-clinical studies in µ-RS: contouring tools, rigid and deformable registrations, planning facilities, plan evaluation tools, dose deformation and summation, etc. Calculation is obtained with a satisfying statistical uncertainty in few minutes. We expect that this new TPS will expand the possibilities of mimicking patient radiotherapy in preclinical studies.

1. Noblet et al., Phys Med Biol, 61, 3521-35, 2016
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4. Terribilini D et al. Medical physics, 37 (10), 5218-5227, 2010.